Spring Issue Volume 15 Number 3 2007

Australian DEFENCESCIENCE

Making the invisible visible

Finding a safe place when airborne weapons head down

Diagnostic smart patch for aircraft

Shapes Vector – world-leading network security system

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
2007		**00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE
Australian DefenceScience. Volume 15, Number 3

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Australian Government,Department of Defense,Defense Science and Technology Organisation,Australia,

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR’S ACRONYM(S)

11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**14**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

CONTENTS

Australian Government
Department of Defence
Defence Science and Technology Organisation

The Defence Science and Technology Organisation (DSTO) is part of the Department of Defence and provides scientific advice and support to the Australian Defence Organisation. DSTO is headed by the Chief Defence Scientist, Dr Roger Lough, and employs about 2200 staff, including some 1300 researchers and engineers. It is one of the two largest research and development organisations in Australia.

Australian Defence Science is published quarterly by DSTO Defence Science Communications. Unless labelled copyright, material may be reproduced freely with acknowledgement.

Managing Editor: Jimmy Hafesjee
e-mail: jimmy.hafesjee@defence.gov.au

Editor: Tony Cox
Phone: 61 8 8259 6554 Fax: 61 8 8259 6191
e-mail: tony.cox@dsto.defence.gov.au

Design and illustration: Rebekah Meere
Phone: 61 3 9626 7141 Fax: 61 3 9626 7133
e-mail: rebekah.meere@dsto.defence.gov.au

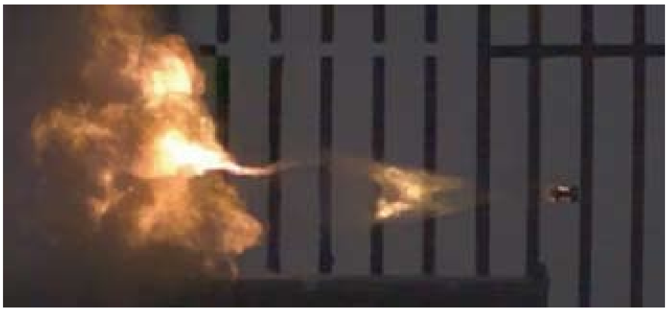
Media enquiries: Lorraine Mulholland
Phone: 61 2 6128 6385
e-mail: lorraine.mulholland@defence.gov.au

Mailing list enquiries: Erinn Ceacis
Phone: 61 2 626 57949
e-mail: erinn.ceacis@defence.gov.au

More information is available about DSTO on its web site at: www.dsto.defence.gov.au

ISSN 1441-0818

High fire-rate weapon **blazing away with success**



High-speed video image of projectile being fired.

DSTO's Mach 5/50 concept demonstrator test-bed device.

DSTO has developed a concept demonstrator device with the capability of firing two projectiles from a single gun barrel at very high muzzle velocities almost simultaneously.

The concept weapon is designed to fire two 60 mm diameter projectiles in rapid succession at muzzle velocities approaching double that of conventional artillery shells, which currently is about three times the speed of sound.

DSTO Program Manager Dr Noel Martin says the objective of the program, known as Mach 5/50, was to demonstrate these capabilities using a test-bed device, and in the process, investigate the efficacy of several novel gun technologies.

The novel technologies under study included electronic ignition, high pressure sealing, ignitor and propellent design, and ballistics instrumentation. Validation of simulation models of internal ballistics was also an important aspect of the program.

Mach 5/50 is a collaborative research program funded by the United States Defense Advanced Research Projects Agency (DARPA), the central scientific research and development organisation for the United States Department of Defense.

Mach 5/50 tests

In 2004, the first test firings of the concept demonstrator were undertaken at the Woomera range in South Australia.

The second phase of testing in 2006, also carried out at Woomera, very successfully demonstrated consistent performance. Improvements on the earlier test-bed being put to trial on this occasion included the development of a more robust and reliable ignition system, and better fire control features.

Part of the success of the test-bed's performance is due to the custom-designed propellant that the team arrived at for the weapon, a process assisted by DSTO's considerable expertise in the area of ballistics propellants.

"The concept demonstrator has been shown to be capable of firing two 60 mm projectiles from the same barrel, without reloading, at shot separation times of 20 milliseconds or less," says Dr Martin.

"In the course of this work, with the assistance of engineers from Vipac Ltd, we had to apply some advanced engineering skills, and we arrived at some unique scientific findings as part of the outcomes," he remarks.

Also notable is the fact that the concept demonstrator was produced well ahead of schedule.

On show at DARPATech 2007

The Mach 5/50 technology was featured at the DARPATech 2007 Systems and Technology Symposium held last August in Anaheim, California, USA.

According to Dr Martin, "Our participation in the event was a great success. This was a very prestigious showcase in which to present our work, with several experts in advanced weapons development from coalition countries taking interest. We were very pleased to be included in DARPATech."

The research program overall, in Dr Martin's opinion, has been a very successful and cost-effective venture.

"It has assisted DSTO in gaining experience and a deeper understanding of some novel gun concepts and technologies, thereby putting us in a stronger position to provide ongoing support to Australian Defence Force in-service and future weapons systems," he says.

A hidden property of light **that makes the invisible visible**

Defence is sponsoring an investigation into military applications for a new technology that can sight targets obscured by natural causes such as smoke, mist and turbidity, or that are intentionally obscured by camouflage.

The research is being carried out under the Department of Defence's Capability and Technology Demonstrator (CTD) program with an Australian company, Iatia Ltd, which has developed the technology.

This work is based on discoveries made by a research group headed by Professor Keith Nugent at the University of Melbourne.

The 3-year, $2.7 million CTD contract signed between Iatia and Defence in June 2005 was the largest project announced under that round of CTD activities.

This venture is the first time that Iatia has worked with Defence. Its world-leading imaging technology is also finding commercial application in other areas such as life sciences research, ophthalmology and nanotechnology.

Making the invisible visible

Iatia's Brendan Allman explains, "The key to this new way of seeing is to harness an aspect of light that is not readily visible.

"When a light wave strikes an object, the object gives off a light wave echo that reveals details about the body's size, shape, surface texture, colour and position. This is similar to the way that a sound wave hitting a wall gives off an echo that acoustically reveals the presence of the wall.

"The light waves echoing from an object are altered in regard to wave amplitude, which we see in terms of brightness, and to wave frequency emission, which we see in terms of colour. The degrees of change in these variables may differ considerably over the surface of an object, and also between objects, creating wide-ranging contrasts that enable us to see them as discrete.

"The interaction of light waves with matter also makes changes to a third aspect of light, known as phase that carries information about shape. This last characteristic is normally undetectable to the unaided eye, but it can be detected and displayed using a technique known as quantitative phase imaging (QPI).

"Crucially for our work, the information about shape is carried by light waves independent of transmission of brightness and colour. It provides a means to discern things using a system of contrast based on degrees of nearness, giving us another way of seeing.

"By boosting the level of the phase signal, which is very weak, we can make out the shape of an object even when it cannot be discerned from contrasts in brightness and colour, like for example when it is transparent or camouflaged."

The QPI technology

The QPI system images objects by using a digital camera in defocused mode to take light phase intensity readings at three planes of capture along the direction of light wave propagation.

The wave front, with the details of the object imprinted on it, gives rise to different distributions of energy intensity across each of the three planes of capture, and these, when combined, can be used to build a picture of the object. The imagery output takes the form of a three-dimensional (3-D) model of the object, with the nearest parts showing in a lighter shade or a different colour than those more distant.

These images can then be further processed by conventional image enhancement and shape-recognition software for improved readability and automated, unmanned handling.

Left: QPI three-dimensional image of man standing, taken from overhead; white blob is head and dark blobs are feet.
Centre: QPI image of ASLAV hidden in bush, taken during recent Puckapunyal trials.
Right: The Psychlops QPI camera used during the Puckapunyal trials.

Micro level applications for QPI

QPI visualisation technology at the microscopic level has already been well developed and proven by Iatia.

It can be used to image objects that are hard to see with conventional light sources, such as thin transparent films, the cells of living things and the optics of the eye.

QPI also has uses in supplementing visual information obtained by sources such as radiography and scanning electron microscopy, revealing details about features that are not otherwise visible.

Hence, it can assist with the inspection of vital component parts that are subject to high stresses, like aircraft engine turbine disks, a capability which is of interest to DSTO.

Other potential areas of use for Defence are those of face recognition for security access and monitoring, and undersea bathyscopy and mine search.

The commercial development of QPI, with its beginnings little more than 10 years ago, only became possible following the advent of digital camera technology and the exponential increases in computing power over recent decades that has enabled fast processing of image information.

Iatia's current QPI system, using commercial off-the-shelf equipment, can process video images at a resolution of 320 x 240 pixels at standard TV frame rates, providing a live imaging capability.

This level of performance is expected to increase as the performance of these supporting technologies also improves, providing improvements in image resolution quality.

Battlefield applications for QPI

Through the CTD project, the QPI technology is being adapted to provide a new way for Australian Defence Force (ADF) personnel to detect and range-find targets, offering significant advantages over other such systems and technologies.

Stereoscopic range finding systems that have long been in use require the simultaneous capture of two images from two separated positions, and since the accuracy of results is dependent on the distance apart of the stereoscopic image capture devices, accurate range finding over long distances requires a large apparatus. Meanwhile, range finding can be carried out also with systems that use laser or radar emissions, but these active sensing procedures are detectable by an enemy force.

In comparison to all these systems, a QPI range finder has the advantages of using just one image gathering device, which includes a capability for wide-angle views, and is entirely passive as a detection system. Moreover, it can detect targets that cannot otherwise be seen in ambient forms of radiation, and it has the capability to do so using electromagnetic frequencies ranging from visible light through the infrared to terahertz waves in the spectral region above microwave radiation.

QPI has been shown to be very effective in revealing shape information in conditions where there are significant levels of particulate material, such as smoke, mist, fog and silt, known as 'scattering media', carried in air or water.

Allman says, "QPI is able to discern an object in scattering media at up to four times the distance we would otherwise be able to see the object."

Additionally, the QPI technology can discern objects that have been deliberately obfuscated with camouflage. While the hue and brightness of the target's colours may merge with those of objects adjacent, disguising the target's outline, the depth features of the target can still be revealed by the phase component of the light waves, thus providing an identifiable image.

A new field eye for the ADF

The camera system developed by Iatia for the ADF is called Psychlops. A prototype version of Psychlops, designed to give the ADF a real-time QPI vision capability, successfully underwent field trials at the Puckapunyal Army Base in May this year.

The trials were conducted with soldiers at around 100 metres – distances indicative of urban and complex terrain scenarios – in various states of camouflage and visibility.

Trials were also carried out on detection of an Australian Light Armoured Vehicle (ASLAV) and one of the new Abrams tanks, which were imaged at ranges of up to 1.5 kilometres through foliage and smoke.

Further work is being undertaken to assess the outcome of the tests and the real capabilities of the technology, with these findings expected to be available in four to six months following a technical review of the work to be undertaken by the DSTO CTD task manager.

According to Allman, "There is every prospect that this imaging technology may also be applied for Defence on underwater and airborne platforms."

Self-powered health-reporting **patch for aircraft**

DSTO has developed a new way of monitoring the structural health of composite bonded patches on aircraft in flight using 'smart materials'. A self-powering prototype was recently flight-tested on a RAAF F/A-18.

Main photo: RAAF F/A-18 with aileron hinge highlighted.
Inset: Data transfer unit placed on smart patch housing to download data.

Achieving a major advance in composite bonded repair technology, DSTO scientists have incorporated health diagnostic abilities into aircraft structures to create a technology known as a 'Smart Patch'.

Bonded composite patches are known to provide a highly efficient and cost-effective means of maintaining the serviceability of components affected by fatigue-cracking or corrosion damage, and they can also be used for reducing strain levels in areas prone to early fatigue damage.

However, with critical components, the certification requirements that must be met to approve repairs as airworthy are very stringent, and this limits the extent to which conventional bonded composite patches can be applied.

In situ health check for critical components

The main advantage offered by Smart Patch is that it provides a means to monitor the health and performance of a patch during active use. Moreover, it provides a continuous assessment of its condition during flight compared to the conventional practice of applying periodic spot checks when the aircraft is grounded for maintenance. The autonomous monitoring is carried out *in situ* for the life of the patch.

These abilities go a considerable way towards alleviating some of the certification concerns for the use of such patches on high value ADF assets.

As DSTO researcher Dr Stephen Galea describes it, "The application of a composite bonded patch with Smart Patch properties leads to enhanced confidence that the patch is functioning as expected by providing an additional level of assurance."

The Smart Patch device, in concept, contains sensors to detect strain, a simple electronic processor and memory to calculate and store patch-health information, and a wireless transmission system for transfer of this data to a ground station for analysis.

A key feature of the Smart Patch is the use of a type of 'smart material' with piezoelectric properties. This material produces an electric charge when stretched or compressed.

By measuring changes in electric charge produced when the material is stressed, it can effectively serve as a strain gauge; similarly, by harvesting the charge generated when the material is stressed, it can also provide all the power needed to operate the device.

The F/A-18 aileron hinge application

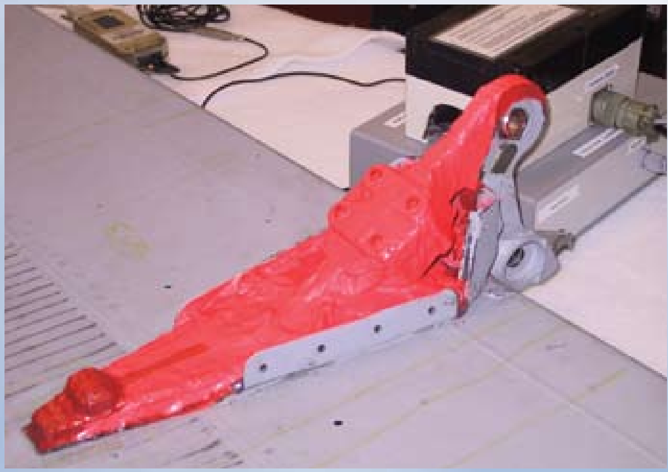
The practical challenge taken up by the DSTO researchers was to devise an *in situ* health monitoring system for a composite bonded patch applied to an F/A-18 aileron hinge – part of the moveable control surface on the trailing edge of the Hornet's wing.

The broad guidelines for the proposed health monitoring system was that the system must be autonomous, robust, easy to install and to gain monitored data from, and require only minimal maintenance if any at all.

A first step in the development process was to establish the conditions under which the patch was required to perform, involving an assessment of temperature, strain and vibration conditions experienced at the aileron hinge during typical flight.

During the design phase, the most appropriate position and geometry for the sensors on the aileron hinge patch was determined, using structural simulation software known as finite element analysis.

A comprehensive installation procedure was written and approved by the appropriate airworthiness authorities, and the system was then installed on an aileron hinge by DSTO personnel over a two-week period under RAAF supervision. This instrumented aileron was fitted to an Aircraft Research and Development Unit (ARDU) Flight Test Squadron (AFTS) Hornet for the flight demonstrator program.



Smart patch device installed on F/A-18 aileron hinge, painted orange to indicate non-standard part.

One of two systems put to test by DSTO used a lithium ion-based battery as the power source, with patch health data downloaded from the patch using a hand-held infrared device.

The other system, considered a higher-risk approach at first but later found to be a more robust option, was powered by energy harvested from operational strains that the hinge was subjected to during flight using piezoelectric elements.

An additional variation incorporated into the second design was that patch health data was downloaded using a hand-held wireless magnetic transceiver.

The trial process shows success in flight

During the trial, data from the patch was gathered by maintenance personnel each week that the aircraft flew.

The hand-held unit was then placed in a docking station that both maintained charge and enabled the downloaded patch health data to be transferred via a GSM mobile phone link to DSTO Melbourne for analysis.

After twelve months of operational flying, data obtained from the Smart Patch indicated that the device was performing as expected, and that the patch was in 'good' health.

"This is a major achievement," explains Dr Galea.

"The Smart Patch self-powering concept has been found to be an effective way to monitor the health of bonded composite repairs to primary aircraft structures. To my knowledge, this is the first time that a self-powered *in situ* structural health monitoring system has been demonstrated on an operational aircraft," he says.

The technology was developed under a RAAF-sponsored task with support from Directorate General Technical Airworthiness-Aircraft Structural Integrity (DGTA-ASI) and ARDU Systems Engineering Squadron (ASES).

Taking a measure of Jervis Bay **for littoral systems testing**

DSTO is carrying out surveys of Jervis Bay to enable its use as a test-bed for accurate scientific evaluation of Defence applications in the littoral zone. Another aim is to enhance ecological management of the bay.

DSTO researcher Les Hamilton describes the Jervis Bay area, which has long been used by Defence for trials, as "a dynamic environment subject to local wave action and the effects of the adjoining South Pacific Ocean, including the East Australian Current and its warm and cold core rings. Currents in the bay can be influenced by phenomena known as coastal trapped waves which propagate northwards from the Bass Strait region."

"The focus of the surveys," explains Hamilton, "is on factors that affect the performance of sensors and systems designed for use in shallow water environments, such as autonomous underwater vehicles, optical remote sensing, and high frequency sonar.

"This work is especially directed to activities such as Rapid Environmental Assessment, a system which combines information from *in situ* observations, remote sensing satellite and airborne sources with geophysical models to make predictions of conditions for military operations.

"We are also investigating methods for collection and processing of environmental data used as inputs for a command and control support tool known as the Recognised Environmental Picture, which provides an assessment of environmental impacts on operational effectiveness during shallow water operations."

The surveys are designed to capture seasonal variations in bay conditions, particularly those of currents, density stratification, turbidity, waves and swell and sonar propagation conditions. Seabed properties, including sediment type and seabed roughness scales, are also assessed.

Above: MV Kimbla used for the Jervis Bay survey.

All these parameters are seen to affect Defence operations in the littoral in some way – such as influencing movements of vessels, mine burial conditions, or modifying sonar propagation.

"For example," explains Hamilton, "if a layer of fresh water overlays a body of saltier water, internal waves may propagate on the density interface between the fresh and salty water, causing unpredictable movement of autonomous underwater vehicles, degrading performance. Internal waves also influence sonar propagation conditions."

The survey tools and processes

The surveys were carried out in the months of February, March and May this year from on board MV Kimbla.

Measurements of water column properties were made at 55 sites during each of the three surveys, with repeat measurements taken at some sites on different days and times to assess short-term variability. Profiles of temperature, salinity, sound speed and turbidity were obtained at each site by small portable instruments deployed by hand, with data recorded by laptop computers.

Measures of water turbidity, know as optical column transparency, were obtained using instruments of vastly different complexity. The simplest of these instruments used was the Secchi disc, a 30 cm diameter white disc, which was lowered into the water until it could no longer be seen, thereby providing a measure known as the Secchi disc depth.

A more sophisticated measurement tool involved the use of a small low-powered laser operating in the visible light range. This was lowered into the water column to obtain a measure of light attenuation with depth. A similar form of instrument measured optical backscatter from suspended particles in the water column at infra-red wavelengths, providing an alternate measure of turbidity.

These turbidity measurements enable estimates to be made of underwater visibility range for clearance divers, and can also be used as calibration data for turbidity estimates obtained by remote sensing from aircraft and satellites. The measurements are useful as well for assessing how turbidity affects the ability of satellite sensors to discern different types of shallow water seabeds, which the sensors do by scanning for tiny amounts of ambient light backscattered from the seabed.

The survey team took measurements of temperature and salinity at different depths in the water column by lowering instruments known

as CTDs that collect data on conductivity, temperature, and depth. This information enables a number of parameters to be calculated, including water density, stratification (a measure of whether the water column is well mixed or not) and sound speed.

Two types of current meters were deployed to measure speeds and directions of currents in the bay. One of these, an electromagnetic type that measures speeds and directions at one point only, was moored near the seabed at the entrance.

Another kind, an Acoustic Doppler Current Profiler (ADCP), was moored near the centre of the bay. This instrument measures currents at different points in the water column from near the seabed to the surface by emitting a beam of high frequency sound at 600 kHz – too high to be heard by organisms – and then measuring the Doppler shift of sound backscattered from small particles in the water column. Both types of current meters were fitted with pressure sensors to record the passage of waves and swells.

A further kind of data collection involved towed video transects of the bay to assess seabed conditions likely to affect military operations. This video data also provides a 'ground-truth' reference point for verifying seabed classifications made by remote sensing, both acoustic and optical, including satellite-based electromagnetic sensors.

Exercise Mulgogger communications aberrations

A dramatic illustration of how the environment can impact on operational effectiveness was seen during the February survey, which coincided with a trial called 'Exercise Mulgogger' being conducted by the Navy for mine clearance operations.

Hamilton explains, "The survey team had made repeated CTD measurements in an area where Navy divers were carrying out tests of mobile underwater acoustics communications equipment. The performance of their communications equipment was known to vary from day to day, and our CTD measurements showed why."

Analysis of CTD data revealed the occasional existence of a differential in temperature of between 3 to 7 degrees Celsius between surface waters and those just a couple of metres below. The researchers determined this was caused by conditions of strong solar heating coupled with the action of sea breezes.

This temperature differential, called a transient thermocline, gave rise to a heightened version of what is known as an 'Afternoon Effect' in which the speed of sound in water is very high at or near the surface but decreases rapidly with depth as it passes into the colder denser water, causing sound waves to strongly diffract downwards.

It was the influence of this phenomenon, in varying degrees on different days, that at times led to short sonar propagation ranges and reduced performance of the acoustic communications equipment.

Trial outcomes

The eventual output of this survey work will take the form of a numerical model of wave-circulation-turbidity for both forecasting and reviewing of oceanographic conditions during trials activities.

In the arena of civil life, the present modelling work will assist the Department of Defence, which jointly manages Jervis Bay with the NSW Government Marine Parks Authority, to better manage this environmentally diverse area by providing fuller understandings of larval dispersal and spread of plankton blooms, and the local factors that affect seagrass growth.

Above: Jervis Bay.
Below: Scientific instruments used in the Jervis Bay survey.

Finding a safe place when **airborne weapons head down**

Anyone positioned in close proximity to live firings of missiles and bomb drops is faced by the concern that the point of impact is always somewhat uncertain due to factors such as possible technical malfunction. DSTO is developing a tool called the Range Safety Template Toolkit (RSTT) that quantifies and displays the levels of risk across an area when these kinds of weapons are launched.

Various organisations within the Australian Defence Force (ADF) have produced and used what are called Weapon Danger Areas (WDA) over many years.

WDAs represent the levels of risk to infrastructure and personnel during weapon trials. These are also known as 'templates', 'safety traces' or 'footprints', though WDA is now the internationally recognised term.

The first step in addressing a risk is to quantify it, and a WDA quantifies the stray round impact risk at various locations on the ground. It is accepted that it is impossible to eliminate risk entirely, and so, a risk threshold at some level – for example, 'one in a million' – may be deemed acceptable for members of the general public in the vicinity of a training range.

A problem with the use of WDAs, as DSTO researcher Duncan Fletcher explains, is that "there is no broadly accepted methodology for generating them. Each weapon has been dealt with on an *ad hoc* basis by the organisation responsible for developing and or authorising WDAs for use."

"Furthermore, modern strike weapons fly a long way. When a WDA is produced for these weapons using the older maximum-range-boundary techniques, the area arrived at can be impractically large.

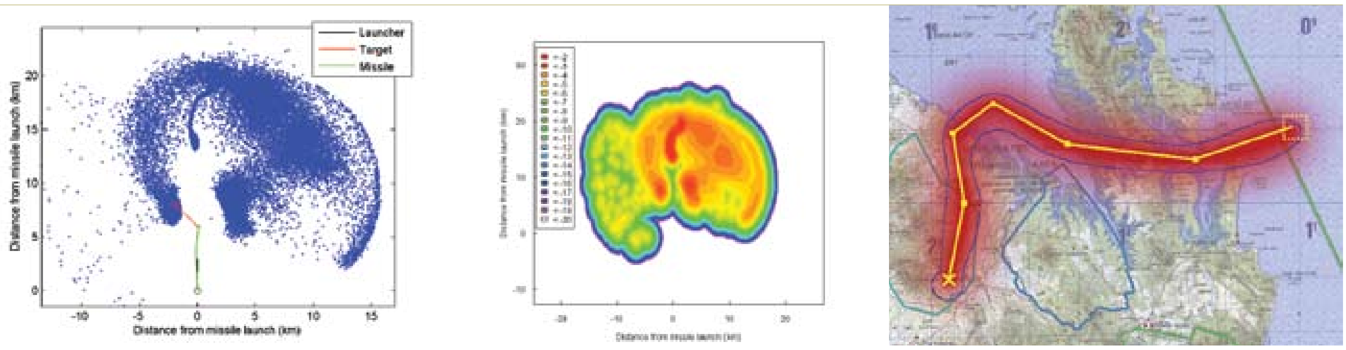
F/A-18 Hornet firing Aim 7 missile.

"We are currently building a simulation-intensive software system that will provide a standardised WDA generation capability, delivering more precise safety threshold boundaries to assist with the ADF's guided air weapon test and evaluation exercises.

"We intend that the system be accepted for general use by the Department of Defence; hence, we are building it in accordance with departmental quality assurance requirements for complex aerospace systems."

The system is being developed by DSTO with the support of RAAF Air Operations Support Group, Australian industry and universities, including Aerospace Concepts Pty Ltd, TRC Mathematical Modelling, the KAZ group, and the University of Adelaide.

Australian Army cavalry scouts fire a Javelin anti-armour missile.



Weapon Danger Area plots with ground impact probability shown in different ways.

Devising a WDA or template

The first part of the process, undertaken by weapons experts, involves preparing weapon-specific databases of simulated ground impacts.

This activity includes inputting data provided by the manufacturer about the weapon's performance as well as potential malfunctions; these latter events are given probability weightings of occurrence. Other relevant data added into contention includes historical meteorological data and missile operational envelopes.

Fletcher explains, "The data preparation system uses a medium fidelity Six-Degree-of-Freedom (6DOF) model of the weapon system, which includes models of Failure Response Modes (FRMs), to generate ground impact distributions. Developing this part of the system to support new weapons can take anywhere from three to twelve months.

"Once the model is built, we start the simulations. For specified launch or release conditions and particular target profiles, we do what are called Monte Carlo simulations using the model and other computer software to determine where the weapon might land for each potential FRM occurring at a random time of flight.

"These simulations are run several million times to get a distribution of ground impacts over a large sample of trials, producing a database of ground impacts that can be used to generate WDAs that are valid for a launch event undertaken anywhere in a user-specified envelope."

The second part of the process is undertaken by operations and range managers with a user-friendly software tool. This tool draws on the weapon ground impact database to develop a WDA for a particular set of launch conditions. Additional information taken on board during the process includes on-the-day wind limits, trial scenario data and geospatial (land survey map) data.

The manner of displaying the WDA data can take different forms.

One mode of depiction is as a contour plot, representing different levels of ground impact probability or risk with different colours. Another requires selecting an acceptable-risk threshold to define the boundary between safe-enough and too-dangerous, depicted as an irregularly shaped outline.

These plots can be overlaid on maps of the intended launch area featuring population demographics and high value assets, and are then used to assess the degree of risk the launch poses to people and equipment. This essentially constitutes a risk map for the trial.

Safety conditions for a launch might be selected to limit the risk of debris impacting within 500 metres of any infrastructure, plus limit the individual risk to any personnel and members of the general public to regulated levels.

If it should happen that the risk of debris impacting outside the firing range boundary is unacceptably high, the launch could be re-planned to take place at a lower altitude or at a different location to avert this predicted hazard.

Easy to use with many applications

The hardware used to run the Monte Carlo simulations and generate the WDAs is standard commercial off-the-shelf computing equipment. The high-fidelity simulations that populate the ground impact database run on a 'farm' of more than a hundred rack-mounted servers. Generating WDAs from the database requires only a simple laptop or desktop PC.

The front-end part of the system has been designed to be readily usable by range and operational personnel, and to provide information that is easily understandable by them as well as relevant outside parties, such as legal advisors and public officials.

By presenting 'quick look' results, it enables rapid assessment of options for operational planning, while also delivering more detailed results in other ways that can be used to support technical assessments. The information it provides has a degree of quality assurance such that it can be used with confidence to support safety-of-life decisions that are legally defensible.

Even in the absence of full weapon technical information, the system is able to calculate WDAs, albeit much larger to compensate for the greater degree of uncertainty in the simulations.

One of the first uses for this tool has been to assist with trials for the ASRAAM air-to-air missile. RSTT is currently scoped to include support for longer range weapons such as the Joint Air to Surface Standoff Missile (JASSM), and sounding rocket launches planned for DSTO's hypersonic research program, HIFiRE. With appropriate enhancements made to the 6DOF model, the tool can be applied to in-service weapons, current procurements and those yet to be developed.

RSTT has uses not only for developmental trials and operational training involving guided air weapons, but also the capability development phase of weapons procurement. This could arise when considering whether a weapon needs a flight termination system, and for operational planning, on how a weapon's collateral risks may impact other aspects of an operation.

RSTT has come to be seen by members of the Defence community within Australia and overseas as an invaluable aid for assessment and safe testing of guided air weapon systems.

Shapes Vector – world-leading **network security system**

As military technologies and operational capabilities become increasingly dependent on computer-based systems and networks for their operation, so too does the need to protect them against attack. DSTO has developed a computer network defence and security management system called Shapes Vector for the Australian Defence Force (ADF).

Attacks on computer systems can take many forms, including spyware intrusions to obtain sensitive information and monitor activity, the insertion of programs that can delete files or corrupt stored information and the operation of programs, and the introduction of self-replicating worms and viruses that cause systems to fail completely through over-congestion.

Such attacks in a military context could cause the loss of strategically sensitive material to an enemy, disrupt vital information flows to mission operatives, and render military platforms largely inoperable – any of which can massively undermine force capabilities.

DSTO researcher Stefan Landherr says, "Ever since the 1980s when hackers managed to get into US military installations, defence establishments around the world have come to recognise the importance of defending their secure networks.

"While many of the initial hackers were motivated merely by the challenge of gaining access to secure sites, the activities of state-sanctioned agents and criminal organisations these days pose a much more sinister threat. Network access control is now a major Defence issue."

DSTO's Shapes Vector

The Shapes Vector software system developed by DSTO offers near real-time monitoring and surveillance of large-scale computer systems and networks. Shapes Vector also allows for replay of stored network data in order to conduct more detailed forensic-style investigations.

Above and opposite: Shapes Vector system in use.

By integrating new techniques in artificial intelligence and three-dimensional (3-D) visualisation, it provides cyberspace situational awareness in the form of a 3-D graphic display showing the various nodes and attributes of a computer network.

The display enables viewers to see schematically where security breaches are occurring in any system area within seconds of the actual event.

This visualisation capability can be readily customised using a range of basic views that depict network operations in different ways, and operators can navigate into areas of particular interest within a visualisation by moving a joystick-type control. In addition to the 3-D visual displays, there are also statistical and tabular views for data mining, system status overview and system configuration and control.

The Shapes Vector display system enables operators to customise the system to their needs to identify activities of concern more readily.

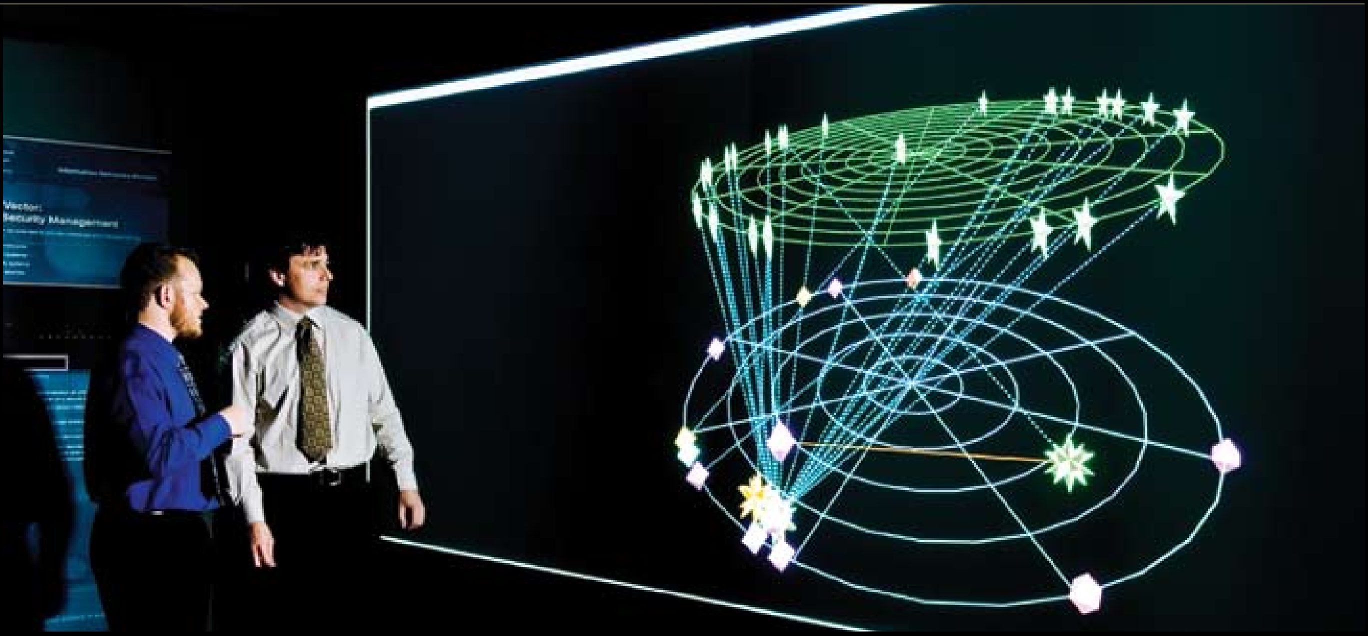
"Shapes Vector is essentially a toolkit of components built upon a common framework," explains Landherr, "and so, can be installed in many different sizes and configurations. Besides the monitoring of large-scale networks, there are also potential applications for smaller, specialised and possibly portable systems."

A core of intelligent agents

The technological heart of the system consists of software components known as intelligent agents. These autonomous software tools, arranged in a hierarchy of several layers, process data gathered by sensors to deductively establish the incidence of security violations.

At the bottom of the hierarchy, agents carry out low-order logic tasks, and the outcomes are fed into agents at the next level that undertake higher order tasks. As the outcomes progress up the hierarchy, they become increasingly abstracted, thus giving the system as a whole a high-level artificial intelligence capability.

"For example," says Landherr, "lower and middle level network agents look for improper or suspicious use of Internet protocols; higher level agents fuse information from lower level agents and look for policy violations or suspicious patterns of traffic flow and user behaviour, sometimes involving



more than one type of Internet protocol. There are also agents that can examine activity logs from important servers.

"The agents communicate by means of an ontology – a domain-specific vocabulary of objects, attributes and relationships. A particular advantage of the Shapes Vector system design is that the agents are arranged in a hierarchical fashion to prevent circularity communications problems that often plague other intelligent agent systems.

"It is this unusual agent structure plus the advanced real-time management features that give Shapes Vector its advantage," he says.

In a further stage of the system process, the deductions from the intelligent agents are sorted into coherent time slices for visual display.

Effective network surveillance

The Shapes Vector system can capture, process and store large volumes of data, enabling security incident analysis and forensic investigation to be carried out for the detection of complex threats and violations.

The process of incident replay and analysis provides a way for operators to determine the origins of threats, and to study the security system failures that have allowed incursions to happen.

The system has been designed to be scaleable so that it can be readily expanded to cope with increases in data flows, and its components can be widely distributed in order to co-locate these with various data sources, such as network taps and server logs. The system's capability for network mapping from zero knowledge has been designed to cope with unplanned changes in configuration, as occurs when personnel plug in or remove information technology (IT) equipment without notifying the system managers.

The main application of Shapes Vector to date has been that of network intrusion detection and security management at the Gateway between the Internet and the ADF's Defence Restricted Network (DRN).

The system operates on both sides of a network barrier called a firewall – a software device that controls the flow of communications traffic between the secure area inside and the non-secure world outside.

Raw network traffic on either side of the DRN firewall is processed to monitor activity at a sample of nodes inside the DRN (particularly the main mail servers and web proxies), the firewall and nodes on the Internet with which Defence users have been interacting.

With several other commercial-grade security systems, such as virus checkers, also operating within the Gateway, the role of Shapes Vector is to detect the more sophisticated and devious styles of malware intrusion, information leakage and user policy violations.

The Shapes Vector advantage

Key features of the system include abilities for real-time monitoring of broad-spectrum data input; ascertaining network configuration from zero knowledge base; versatile recording, replay and visualisation of incidents with sophisticated reconstruction and analysis; monitoring of specific organisational and business policies; and an extensible, open, distributable architecture.

According to Landherr, "While a number of other advanced computer security systems have emerged in recent years, the Shapes Vector system remains unique in terms of its data processing and display capabilities.

"Although it is possible to find pieces of some Shapes Vector functionality in various other computer security tools, Shapes Vector offers the significant advantage of being an integrated system. This integration confers several practical benefits, including simpler management, reduced training and lower staffing," he says.

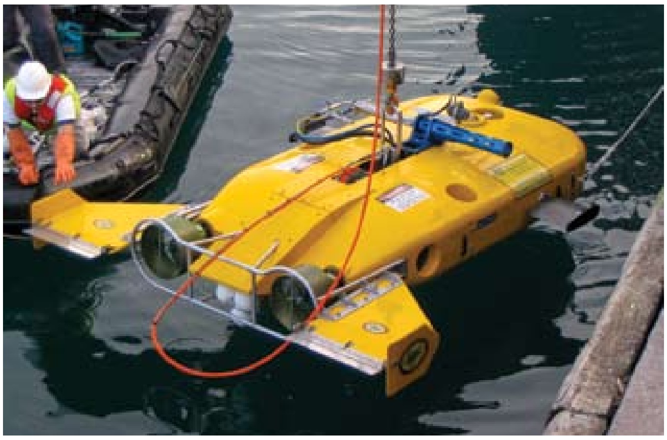
During trials in Australia and the US from 2001 to 2005, Shapes Vector was shown to be capable of revealing security violations not detected by other such systems.

In mid-2006, an operational roll-out of the Shapes Vector system was undertaken by the Defence Network Support Agency, and an enhanced version with more capable hardware was installed at the Defence Network Operations Centre.

Shapes Vector attained operational status earlier this year, and is now routinely used to monitor the Defence Internet Gateway as part of a suite of technologies and systems for computer network defence.

Getting torpedo decoys **out to do their job**

A vital form of defence for submarines against torpedo attack is the use of decoys to lure torpedos away. DSTO has been carrying out research to ensure that the newer kinds of these devices, which are deployed by ejection from the submarine, get clear of the craft effectively.



The level of threat posed by the sophisticated torpedos in use today is such that particular vessels can be tracked by identification of their wake and sonar signatures, using targeting data captured by the torpedo itself or fed to it by wire from external sources.

To counter this threat, torpedo decoys can be deployed to mimic the wake and acoustic signals of the target, thereby luring a torpedo away from the target vessel to either impact with the decoy, or to delay the torpedo's onset by creating confusion and giving the boat an opportunity to outrun or evade the torpedo.

The problem for deployment of these devices from a submarine moving at high speed is to ensure that these devices clear the wake of the boat to avoid being temporarily caught up and captured by the wake. This issue similarly applies to the deployment of signal flares.

Simulation tools for problem study

"To study the problem," explains DSTO researcher Brendon Anderson, "we have developed a computer model that simulates the trajectory of projectiles launched from a submarine. This enables us to make an assessment of the likelihood of the projectile recontacting the submarine.

"This model, being used for Collins class submarines, combines hydrodynamic modelling of the submarine wake and the decoys in three dimensions, allowing for studies in which the changing course of the submarine and projectile can be simulated for various manoeuvres," he says.

Above: DSTO's UUV research vessel Wayamba *fitted with torpedo decoy ejection mechanism.*

However, to ensure that the findings of the modelling work can be used with confidence, the modelling results must be validated by trials carried out in real-world conditions.

To this end, a series of field trials are being undertaken with firings from an ejection mechanism fitted to DSTO's unmanned underwater vehicle (UUV) test-bed, *Wayamba*. The first series of trials were carried out in Corio Bay, Geelong, earlier this year.

Real-world validation trials

A purpose-made generic projectile was used together with a launching mechanism powered by compressed air that enabled firings from *Wayamba* off its starboard side while in motion.

The projectile measured about 75 mm in diameter and 600 mm long in fully assembled form, with optional designs for three different tails and two noses being tested during the trials. Weighing around 2.5 kg, the projectile was fitted with internal weights to achieve the desired buoyancy and trim.

The launcher mounting design enabled launches up to 45 degrees forward or rear of the normal launch position. The launch system delivered a force up to 25 times that of gravity. This allowed a series of launches of the projectile to be carried out at a range of launch speeds of up to ten to twelve metres per second.

The dynamics of the launchings were measured by an inertial motion unit – a device designed to record changes in acceleration and direction – on board the projectile.

This data was downloaded from the device by accessing the electronics via a removable plug at the rear of the projectile, and then taken back to DSTO for analysis to study how the projectile performed under different launch conditions.

In addition to the current field work, a final set of trials will be conducted later this year to obtain more data for comparison with the modelling results produced by DSTO's computer simulations.

Left: Generic projectile for torpedo decoy trials with optional nose and tail design fittings.
Right: Generic projectile under way during a trial.

Net Warrior boosts NWC research capabilities

DSTO has improved on communications between its synthetic environment experimentation facilities in a major enhancement of its capabilities to develop new joint warfighting strategies for the ADF.

The initiative, known as Net Warrior, involves the Battle Lab facilities operated by eight divisions of the organisation, along with those of defence industry contractor Boeing Australia Limited.

Through Net Warrior, multidisciplinary technological and systems issues that are being studied in isolation can now be investigated jointly in a single environment.

These areas of interest include platform connectivity, mission systems integration, multi sensor integration, weapon system integration and human system integration.

This development is seen to enable a revolutionary improvement in DSTO's network centric warfare research capabilities, a key strategic initiative of the organisation.

F-111 F-WELD fatigue test completed

Over the past three years, DSTO has conducted a wing fatigue test known as the F-111F Wing Economic Life Determination (F-WELD).

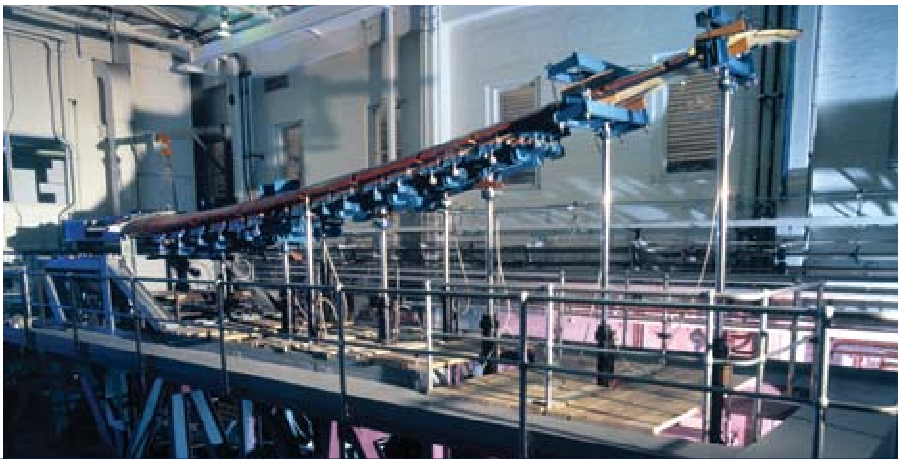
The test achieved 38,000 simulated flying hours in July this year. This testing is being undertaken to support the full life expectancy of the wings fitted to RAAF F-111 aircraft.

The test wing was then inspected using an automated ultrasonic inspection system while loading was applied to the wing in the test rig. The application of loading opens any cracks and thus makes them more readily identifiable.

Pinpointing the location of potential cracks in the lower wing skin Taperlok fastener holes will greatly assist the next phase of the work. This involves a teardown inspection in which the wing is completely disassembled into its component parts.

Extensive manual non-destructive inspection will be undertaken to identify cracks in other parts of the structure. The identification of fatigue cracks will be followed by analysis of the resultant fracture surface to gather crack growth data.

The data will help with the ongoing management of the wings up to the planned withdrawal date of the RAAF F-111 aircraft.



F-111F wing in F-WELD test rig.

New capability technology centre to be established

The Australian Government recently announced plans to set up a cooperative venture known as the Defence Future Capability Technology Centre (DFCTC).

Its intended purpose is to foster greater collaboration between Australia's publicly-funded research organisations, pre-eminent universities and industry product developers in order to nurture the high levels of innovation essential for maintaining the nation's technological capability edge in defence.

It is envisaged that the new centre, constituting a partnership between Defence and the Department of Education, Science and Training (DEST), will adopt many of the characteristics of the broader Cooperative Research Centres Programme administered by DEST.

A call for applications from interested organisations was issued during the months of August and September this year, with a decision on successful applicants to be made by the end of the year.

Areas of expertise to be developed by the formation of DFCTC will include one or more of the following: Integrated Battlespace and Systems Integration; Chemical, Biological, Radiological, Nuclear and Explosives Defence; Autonomous Systems and Robotics; Materials Sciences, Electronic Warfare Self Protection; and High Energy Electromagnetics.

Australian Government funding available for the DFCTC Program will amount to about $30 million over seven years. The centre is expected to be operational by mid-2008.

CALENDAR

8 - 10 Oct 2007	Modelling and Simulation 2007 Beijing, China http://www.iasted.com/conferences/home-571.html
9 - 10 Oct 2007	Defence Human Sciences Symposium Melbourne Email: peter.blanchonette@dsto.defence.gov.au http://www.dsto.defence.gov.au/events/dhss/
16 - 19 Oct 2007	IPE 2007 Rydges Melbourne http://www.sainc.com/ipe2007/index.asp
22 - 26 Oct 2007	Land Warfare Conference Convention Centre, Adelaide Tel: 08 8259 6719 Email: vinod.puri@dsto.defence.gov.au http://www.dsto.defence.gov.au/events/5021
19 - 21 Nov 2007	Intelligent Systems and Control 2007 Cambridge, Massachusetts United States of America http://www.iasted.com/conferences/home-592.html
20 - 22 Nov 2007	MilCIS 2007 National Convention Centre, Canberra http://www.milcis.com.au/
29 - 31 Jan 2008	RAN Sea Power Conference 2008 Convention & Exhibition Centre, Sydney http://www.seapower2008.com
29 Jan - 1 Feb 2008	Pacific 2008 Convention & Exhibition Centre, Sydney http://www.pacific2008.com.au
13 - 15 Feb 2008	Signal Processing, Pattern Recognition and Applications Innsbruck, Austria http://www.iasted.com/conferences/home-599.html
26 - 28 May 2008	Wireless and Optical Communications Quebec City, Canada http://www.iasted.com/conferences/home-621.html
23 - 25 Jun 2008	Applied Simulation and Modelling Corfu, Greece http://www.iasted.com/conferences/home-609.html

ADS15/3-009/2007 Cover image: Shapes Vector system in use.